

REMARKS

Applicants respectfully request that the amendment be made to the Specification in order to refer to FIGS. 2A and 2B. These changes are necessary because FIG. 2 has been broken up as FIGS. 2A and 2B to properly show elements therein.

With this amendment, applicants provide substitute drawings with FIGS. 2A and 2B separated as indicated above.


Applicants respectfully request entry of this Preliminary Amendment prior to the first Official Action and prior to calculating the fees for the application.

The Director is authorized to charge any fee deficiency required by this paper or credit any overpayment to deposit account No. 23-1123.

Respectfully submitted,

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**MARKED-UP VERSION OF REPLACEMENT PARAGRAPHS**

**Please replace the paragraph starting at page 3, line 18 and ending at page 3, line 19 with:**

FIGS. 2A and 2B are ~~is a~~ sectional views taken along line 2-2 of FIG. 1A and ~~including a~~ schematic diagrams illustrating placement of sensors on the load cell.

**Please replace the paragraph starting at page 6, line 7 and ending at page 6, line 31 with:**

In a preferred embodiment, each of the tubes 21-28 includes a plurality of spaced-apart wall portions of reduced thickness to concentrate stress therein. Referring to FIGS. 2A and 2B and tube 21 (FIG. 2A) by way of example, the tube 21 has a non-rectangular outer surface 31 wherein the wall portions of reduced thickness are indicated at 33A, 33B, 33C and 33D. The wall portions of reduced thickness 33A-33D are formed by a cylindrical bore 75 in the tube 21 and a first pair of parallel planar surfaces 37A and 37B facing in opposite directions and a second set of planar surfaces 39A and 39B also facing in opposite directions. The second set of planar surfaces 39A and 39B are substantially orthogonal to the first set of planar surfaces 37A and 37B such that the planar surfaces of the first set and the second set are alternately disposed about the corresponding longitudinal axis of tube 21. Although illustrated wherein the thickness of the portions 33A-33D are approximately equal, if desired, the thickness can be made different to provide desired sensitivity in selected directions. Preferably, the thickness of portion 33A should be approximately equal to portion 33C, and the thickness of portion 33B should be approximately equal to portion 33D.

**Please replace the paragraph starting at page 6, line 32 and ending at page 8, line 5 with:**

The strain sensors are mounted on the first pair of parallel planar surfaces 37A and 37B and the second set of planar surfaces 39A and 39B. Planar mounting surfaces can be advantageous because measured output signals have lower hysteresis and lower creep gauge bonding due to uniform gauge clamp pressure on flat surfaces versus curved mounting surfaces, which locks residue stress in gauge. Also, alignment scribing and affixing of the gauges to the scribed lines is more difficult on a curved surface. The non-rectangular outer surface 31 is also beneficial because this form concentrates stress in portions of the tube 21, which are proximate the strain sensors. Although a tube having a rectangular cross-section (four flat surfaces that intersect at the corners) can be used, significant stress concentration occurs at the intersection of the flat surfaces where strain sensors cannot be easily mounted. Thus, performance is substantially reduced. In contrast, the non-rectangular tube 21 illustrated in FIG. 2A includes planar surfaces 41A, 41B, 41C and 41D that extend between each planar surface of the first set and the successive planar surface of the second set. In a preferred embodiment, the planar surfaces 37A, 37B, 39A, 39B and 41A-41D preferably form an octagon in cross-section. Forming each of the tubes 21-24 with an octagonal outer surface 31 simplifies construction and reduces manufacturing costs since the planar surfaces can be easily machined. Although illustrated wherein one planar surface extends between each planar surface of the first set and successive surface of the second set, for example, planar surface 41A, it should be understood that a plurality of intervening planar surfaces can be used. Similarly, the flat planar surfaces 41A-41D can be replaced with curved wall portions to form a non-rectangular tube. Such a tubular structure does not have an annular wall of uniform thickness, but rather the spaced-apart portions of reduced wall thickness 33A-33D again created by the flat surfaces

37A, 37B, 39A and 39B concentrate stress therein similar to the octagonal cross-section.

**Please replace the paragraph starting at page 9, line 4 and ending at page 10, line 3 with:**

FIGS. 2A, 2B, 3A and 3B illustrate location and connection of the strain gauges into the sixteen Wheatstone bridges mentioned above. Generally, each tube includes a first pair of strain sensors 50 provided on a first portion (surface 37A) of each tube 21-28. A second pair of strain sensors 52 is provided on a second portion (surface 37B) approximately 180 degrees from the first pair of strain sensors 50. The first and second pairs of strain sensors on each tube 21-28 are connected in a conventional Wheatstone bridge to form a first sensing circuit on each tube 21-28. The first Wheatstone bridge senses forces along one of the axes 33 or 35.

Specifically, in the embodiment illustrated, forces along the X-axis 33 are calculated from output signals from the first Wheatstone bridge provided on each of the tubes 21, 22, 25 and 26. Similarly, output signals from the first Wheatstone bridge on each of the tubes 23, 24, 27 and 28 are used to calculate forces along the Z-axis 35.

Each of the first Wheatstone bridge circuits are shear sensing circuits. A second sensing circuit on each of the tubes 21-28 sense axial tension/compression along the Y-axis 15. Each of the second Wheatstone bridge circuit includes a third pair of sensors 54 mounted on a third portion (surface 39B) approximately 90 degrees from the first pair of sensors 50, while a fourth pair of sensors 56 is mounted on a fourth portion (surface 39A) approximately 180 degrees from the third pair of sensors 54. In the embodiment illustrated, two poisson gauges in each of the second Wheatstone bridges (axial bridges) are not fully active like all of the sensors in the first Wheatstone bridges (shear bridges).

**Please replace the paragraph starting at page 10, line 4 and ending at page 10, line 20 with:**

FIGS. 3A and 3B are schematic diagrams illustrating connection of the Wheatstone bridges on tubes 21-28 in order to realize eight output signals from the load cell 10. In essence, pairs of similar sensing Wheatstone bridge circuits are connected together to provide an output signal of a virtual tube disposed between each of the tubes. For instance, a first Wheatstone bridge circuit 218 of tube 21 is indicated at 401 in FIG. 2A, while a first Wheatstone bridge circuit 220 of tube 22 is indicated at 403 in FIG. 2B. The Wheatstone bridges 218 and 220 effectively form a single output signal for a virtual tube 402 located between tubes 21 and 22 in FIGS. 2A and 2B. Resistors 278 and 280 are provided and chosen to match sensitivity of each of the Wheatstone bridge circuits 218 and 220 in order to combine the outputs thereof and effectively form one output signal.

**Please replace the paragraph starting at page 11, line 15 and ending at page 11, line 27 with:**

As appreciated by those skilled in the art, it is not necessary that the Wheatstone bridge circuits be combined as illustrated in FIGS. 3A and 3B in order to practice the present invention. In other words, the output signal provided by each Wheatstone bridge can be obtained wherein suitable hardware or software is used to resolve each of the corresponding output signals with respect to the coordinate system of orthogonal axes 33, 35 and 15. However, connection of the Wheatstone bridges as described above and illustrated in FIGS. 2A and 2B can realize manufacturing cost savings by reducing the number of output signals provided from the load cell 10.